Polymer solar cells

Krebs, Frederik C

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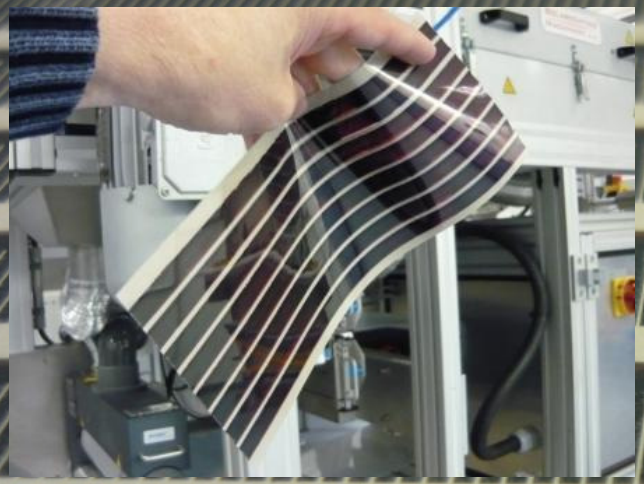
DTU

RISØ

Polymer Solar Cells

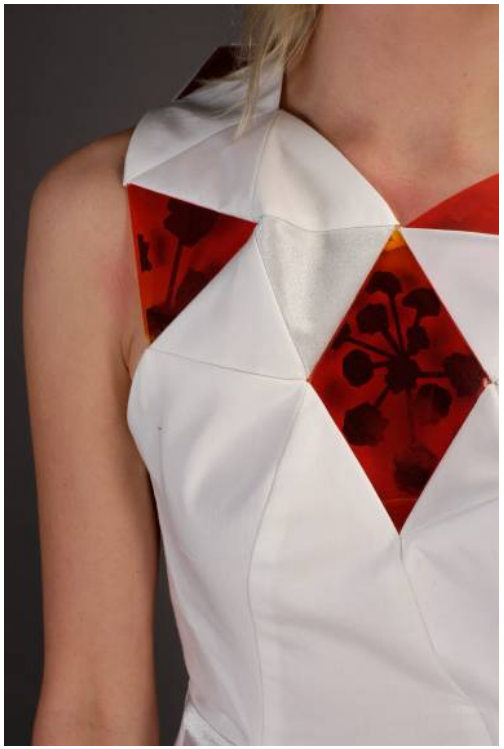


Overview

- What constitutes a polymer solar cell
- What is the potential and why the interest
- Where is the technology today
  - Performance
  - Stability
  - Processing
- Status at Risø DTU
- Outlook
- Conclusions

What constitutes a polymer solar cell

- The carrier substrate may be a polymer (or plastic) material
- The active material is a polymeric material
- Typically it is a multilayered structure
- Flexible



What is the potential and why the interest

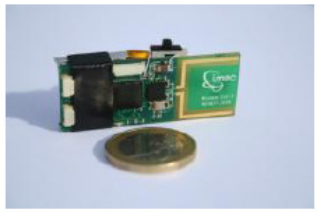
- All other solar cell technologies have consitently failed when it comes to reduction of cost

Microdevices

Smart Packaging

Source: Aveso Displays

Wireless Sensors



Source: IMEC

Consumer Products

Battery Charging

Active Clothing

On-Grid Power

Off-Grid Power

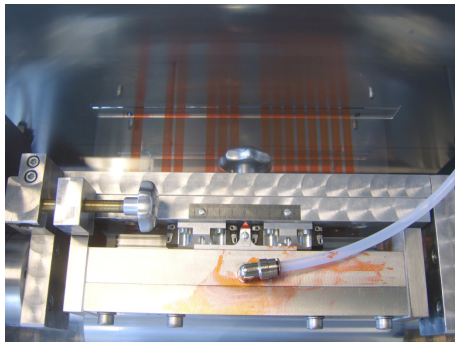
Rural Power

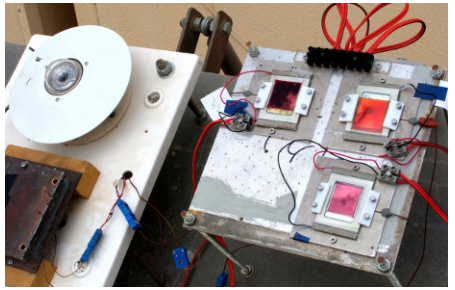
Transportation

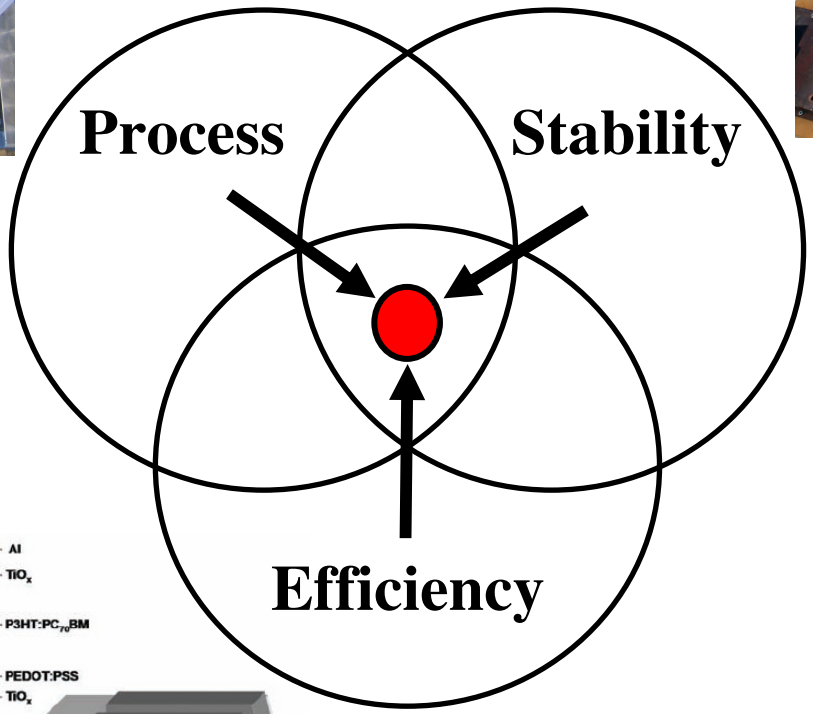
OPV Potential

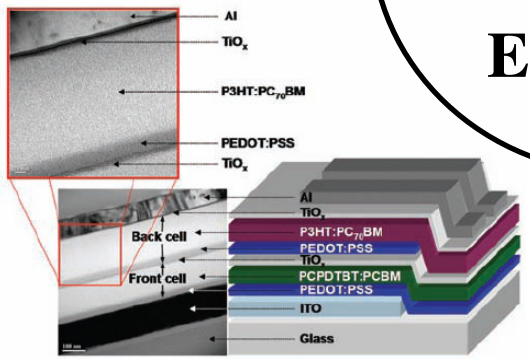
- Operates well under various lighting sources
- Low dependence on angle of incidence
- Flexible/conformable form factor
- Long-term attractive LCOE

Where is the technology today



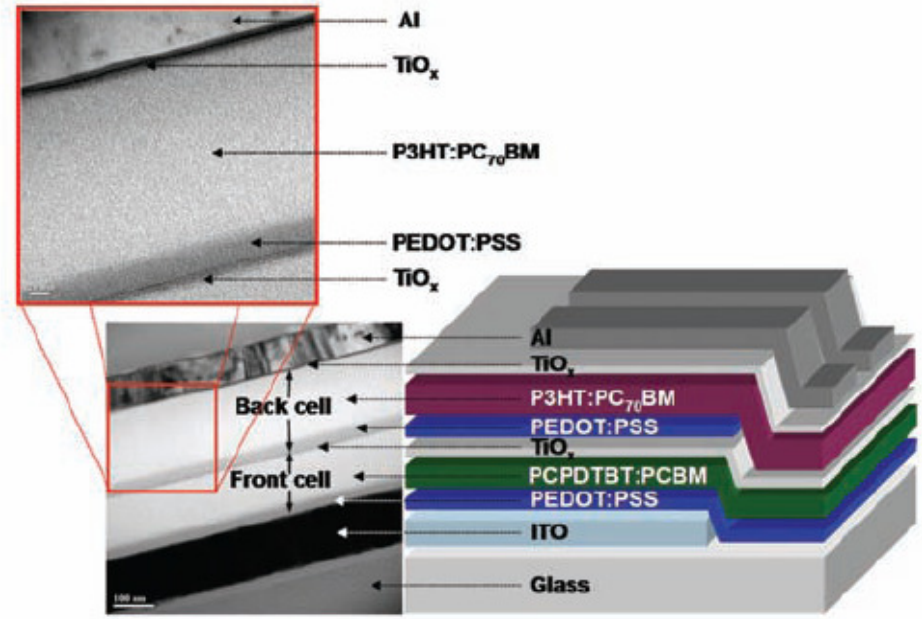






Performance

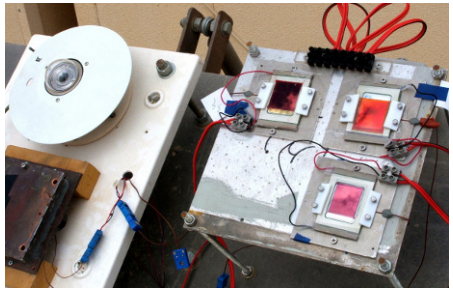
- **6.5% For tandem cells 5% for single junctions**
- > 99.9 % of scientific reports have efficiency as the selling point
- > 99.9 % of scientific reports employ spin coating
- > 99.9% of scientific reports employ evaporated metal back electrodes
- > 99.9% of scientific reports employ indium based transparent electrodes

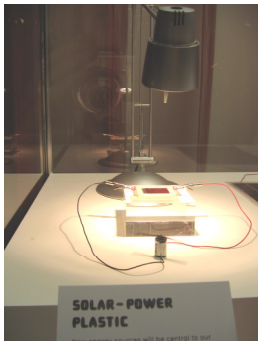


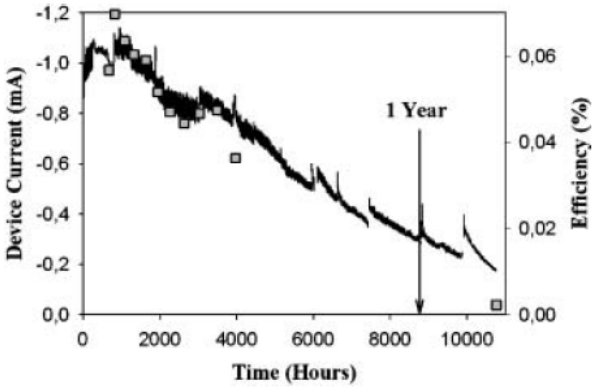
Science 317 (2007) 222.

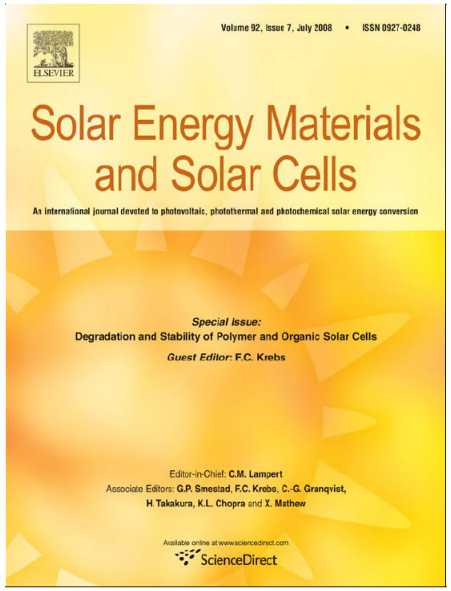
Stability

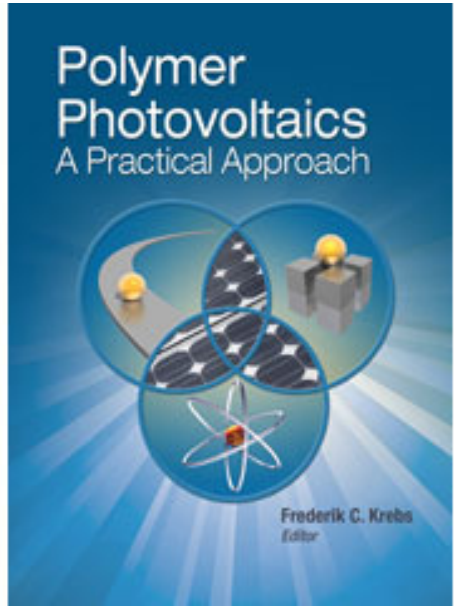
- Rarely reported/documented – while this is starting to change

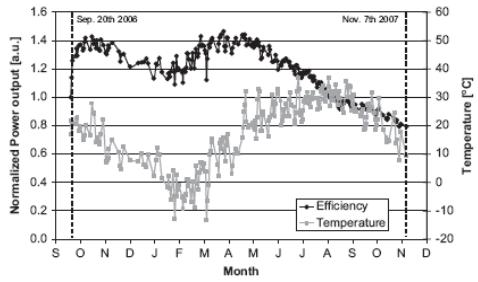








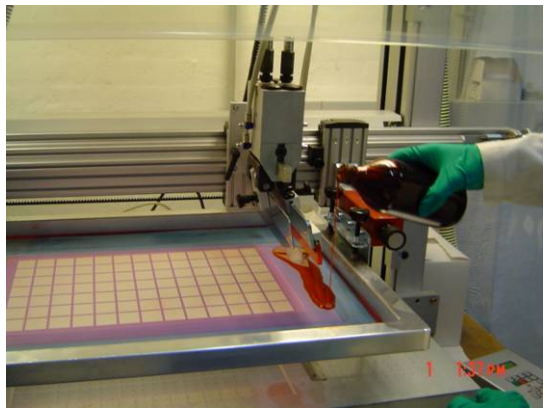




Jørgensen et al. Sol. Energy Mater. Sol. Cells 92 (2008) 686-714.
Hauch et al. Sol. Energy Mater. Sol. Cells 92 (2008) 727-731.
Krebs et al. Prog. Photovolt.: Res. Appl. 15 (2007) 697-712.

Processing

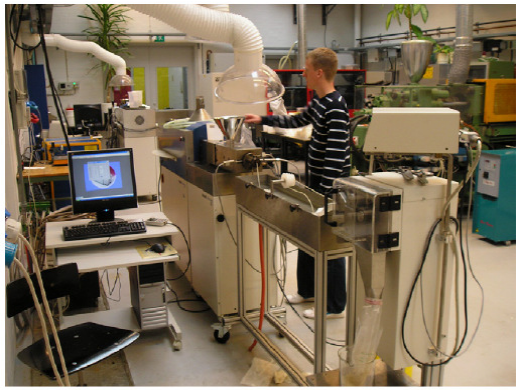
Processing is still rather unexplored and limited to a few materials using virtually one single film forming technique.

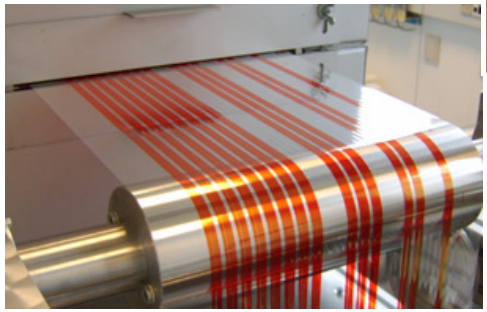


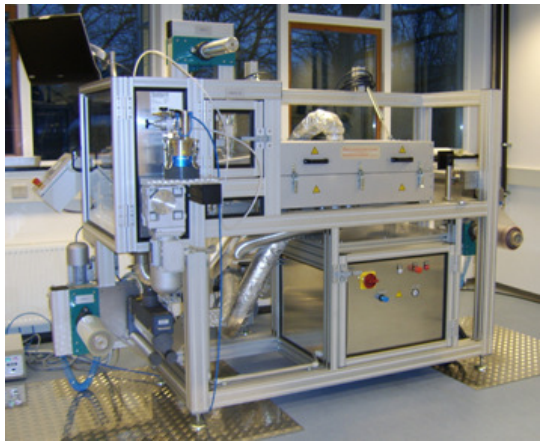
Adv. Mater. 19 (2007) 3973-3978.
Appl. Phys. Lett. 92 (2008) 033306.
Mater. Sci. En. B 138 (2007) 106-111.

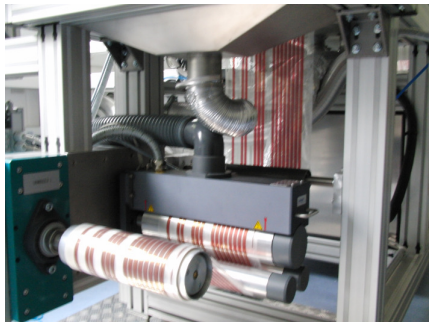
New materials and processing techniques are needed

- Low cost
- Fast
- R2R
- Ambient air
- No vacuum steps
- Environmentally friendly



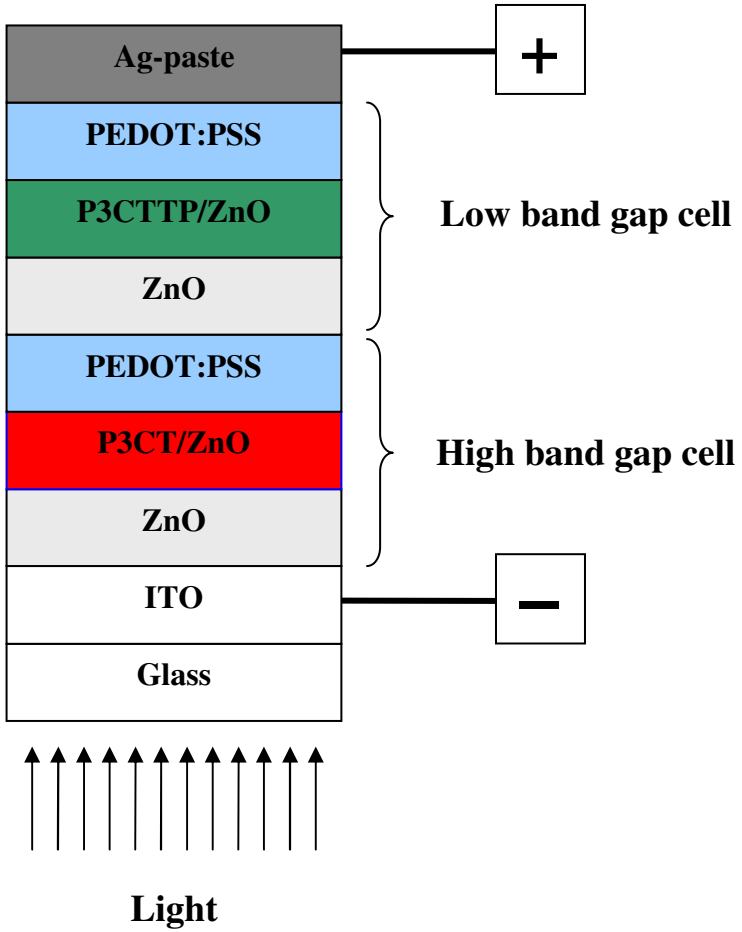


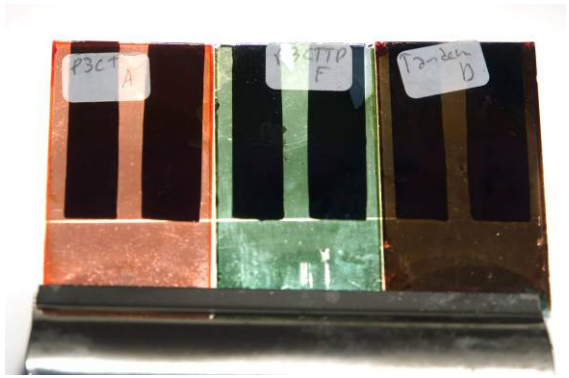


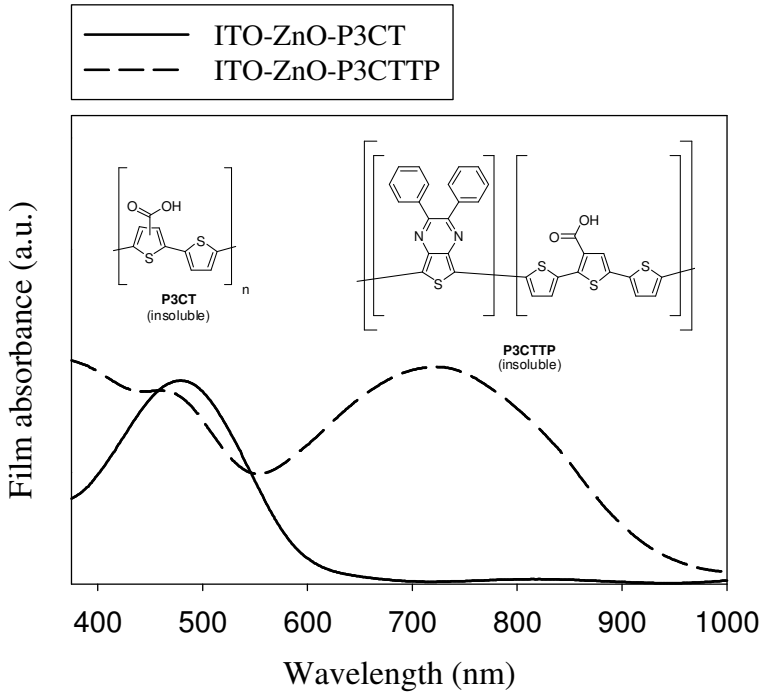


Sol. Energy Mater. Sol. Cells 92 (2008) 805

Multilayer processing







Sol. Energy Mater. Sol. Cells 92 (2008) 1327

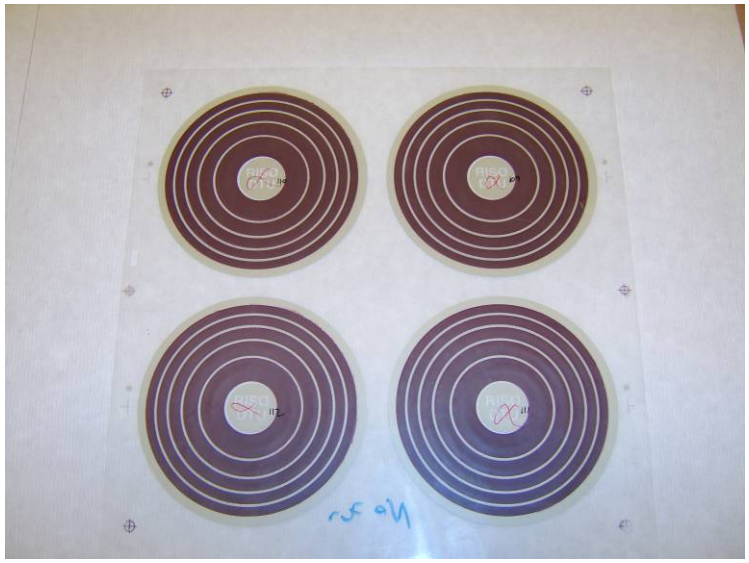
Real world demonstrations

- Many challenges for the development of the process that compromised performance
  - No volatile solvent
  - No toxicity
  - Air stability of printing ink
  - Long open time on mask
  - Solution to large wet thickness obtained with screen printing
  - All 5 layers had to be processed by screen printing

- Demonstration in July 2008

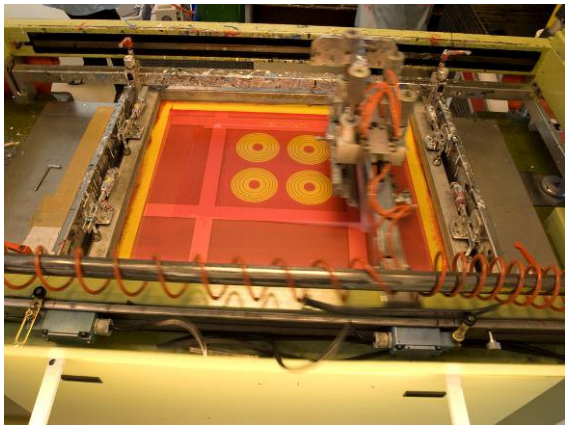
Real world demonstrations

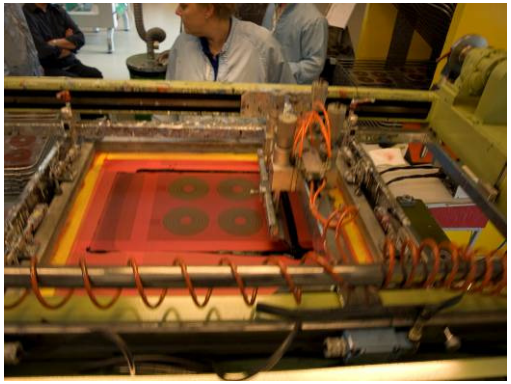
- Concept/Mock-up



Real world demonstrations

- Processing entirely by screen printing
- All steps done in ambient air
- No special requirements to processing atmosphere





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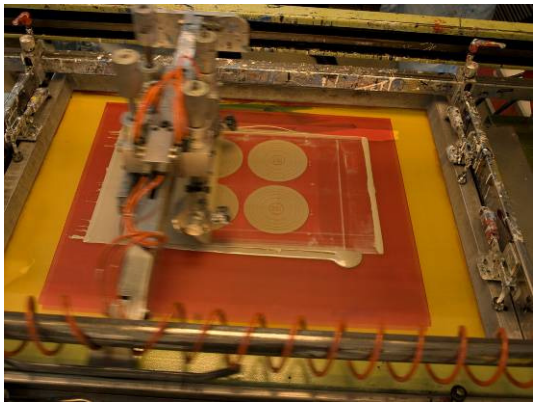
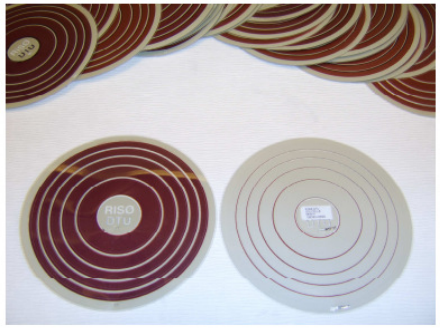
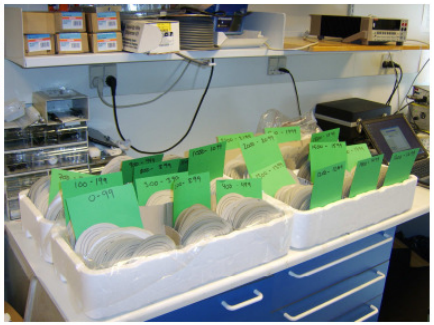


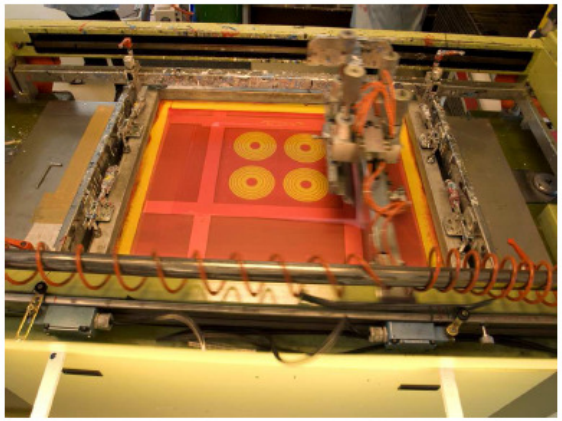
How did it go

Cold laminated PET with acrylic resin (25 µm)
Ag-paste (6 µm)
PEDOT:PSS (250 nm)
P3CT/PCBM/ZnO or P3CT/ZnO (90 nm)
ZnO (30 nm)
ITO (80 nm)
PET (175 µm)

~ 210 µm

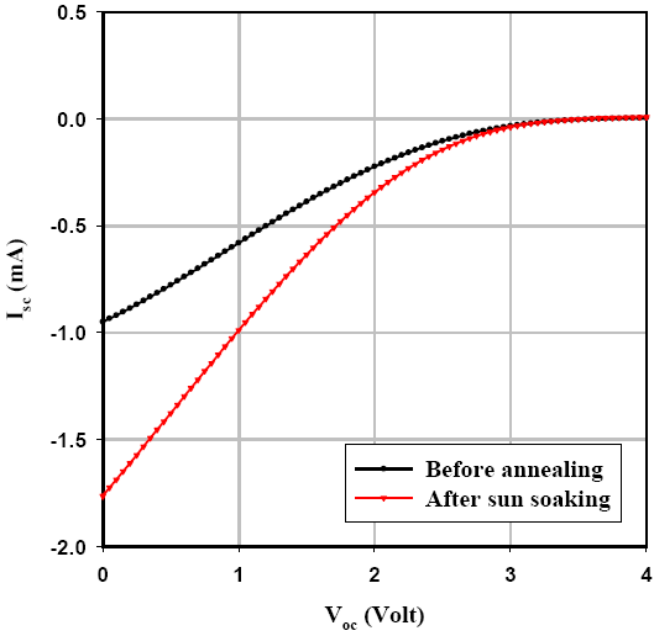


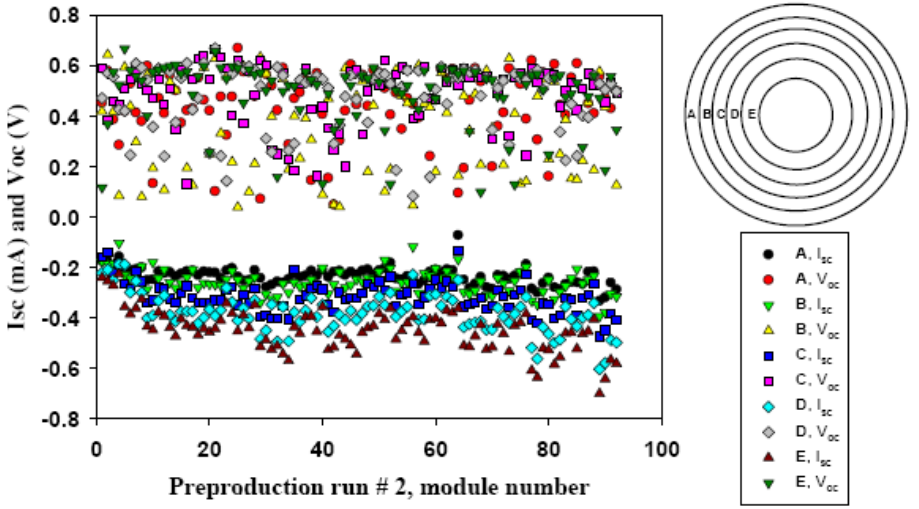


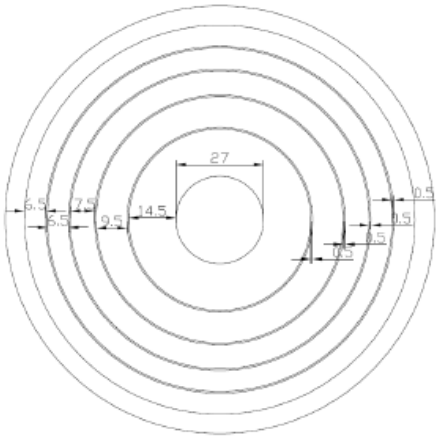


2124 functional modules produced in final run

How did it go

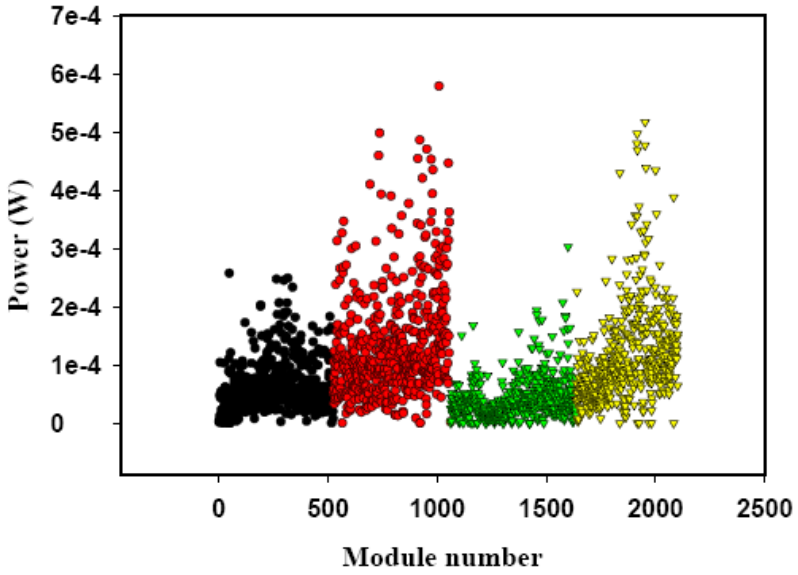


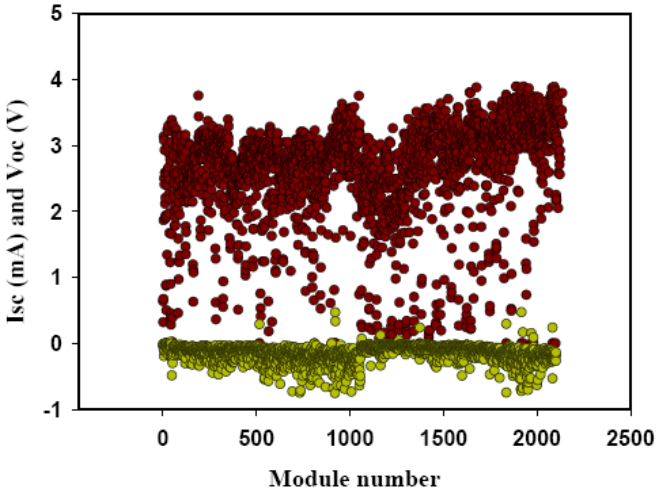


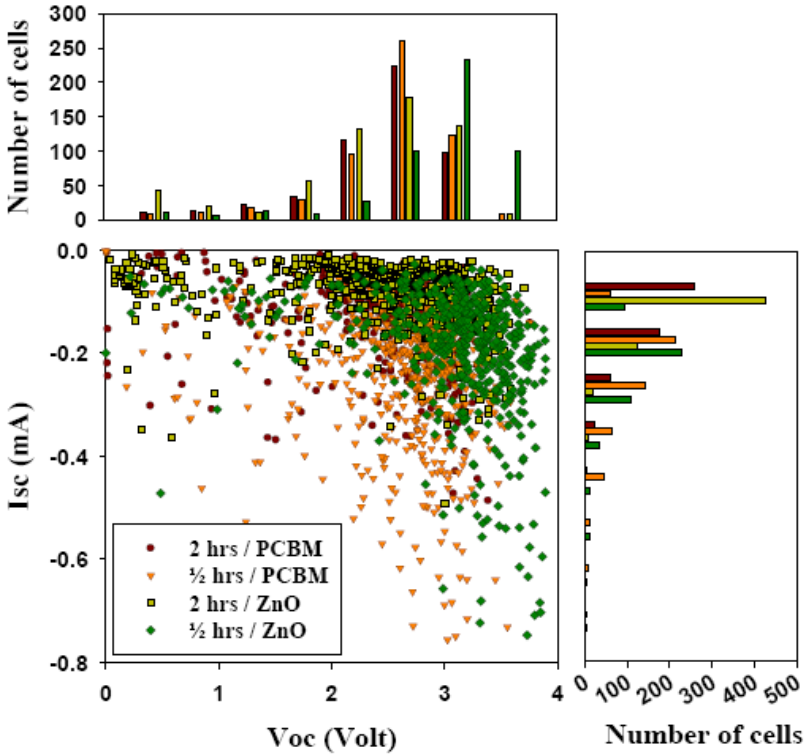


Prerun #2/3

How did it go

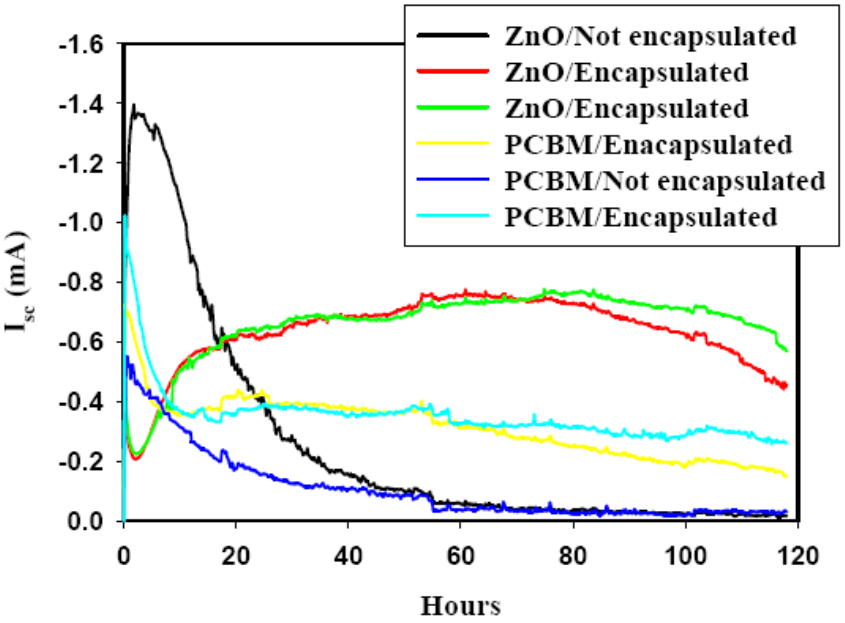

Power (W)
7e-4
6e-4
5e-4
4e-4
3e-4
2e-4
1e-4
0
0
500
1000
1500
2000
2500
Module number


Isc (mA) and Voc (V)
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Module number


Number of cells
300
250
200
150
100
50
0
Isc (mA)
0.0
-0.2
-0.4
-0.6
-0.8
2 hrs / PCBM
½ hrs / PCBM
2 hrs / ZnO
½ hrs / ZnO
0
1
2
3
4
Voc (Volt)
0
100
200
300
400
500
Number of cells

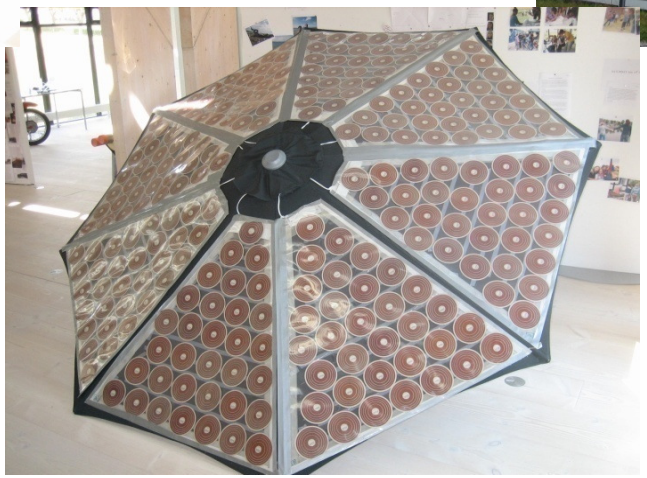
Roskilde festival (Denmark)

Module cost complete	~ 4.5 Euro
Processing cost	~ 1.5 Euro
Materials cost	~ 3.0 Euro
Cost savings:	
Minus ITO	~ 3.2 Euro
Minus crimping	~ 2.5 Euro
New printing method	~ 1.5 Euro

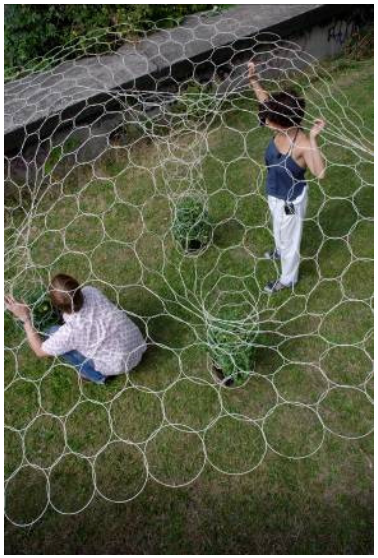


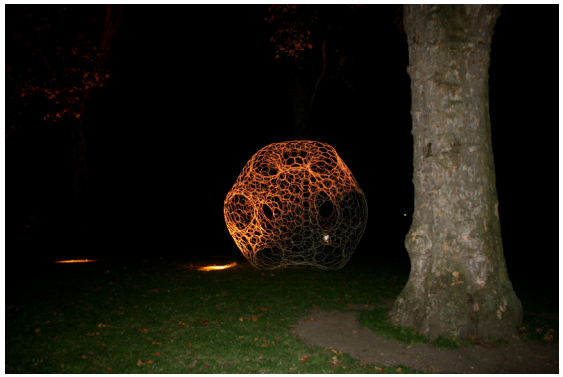
Samsø Energy Academy

- Promotes Danish sustainable energy.
- Permanent exhibition of polymer solar cells.



St. James Park (Loop.PH, London)





Status at Risø DTU

- We believe in the full package (materials, processing and perfromance)
- First public demonstrations in 2008
- Several processes available
- ProcessOne
  - 2.33% PCE, full R2R, all solution, all air, semitransparent, flexible

Outlook

- The technology is likely to appear in niche products in 2009 onwards
- Potential for low cost and energy savings demonstrated
- On-grid electrical energy production lies somewhere in the future (10-20 years)

Conclusions

- We must find convincing means to combine efficiency, stability and process, thermocleavable materials is one possibility
- Many processing techniques are available that should be explored
- An application example is given, and, while being far from anything that can be rated as a commercial product, it shows some level of feasibility
- Cost analysis show that it is possible to prepare a low cost polymer PV product, but also that it will only come at an effort.